

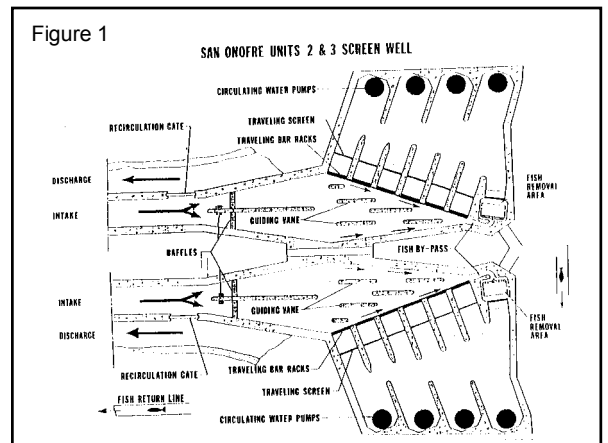
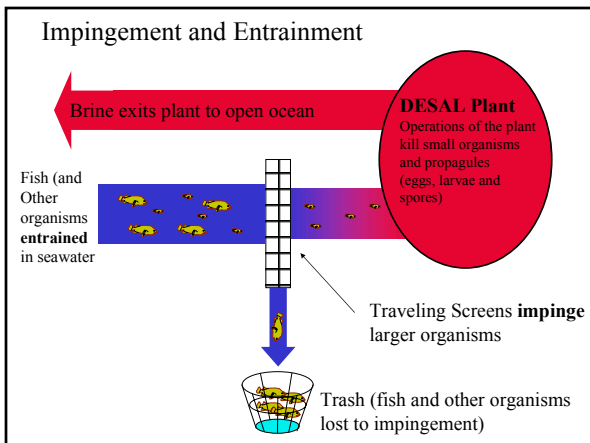
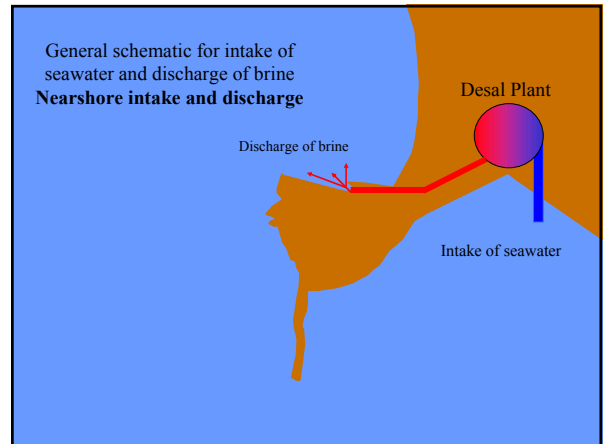
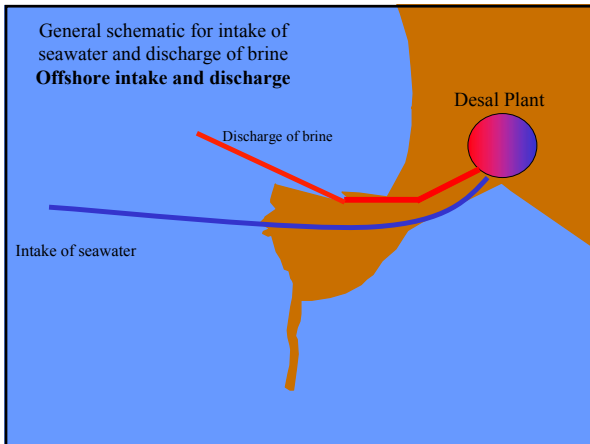
# Estimation of ecological impacts due to use of seawater in a desalinization facility (in a NEPA / CEQA context)

- **Impingement**
- **Entrainment**

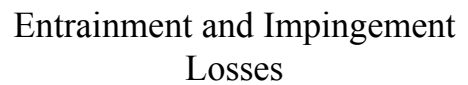
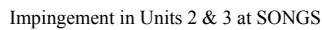
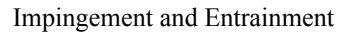
Pete Raimondi, Professor and Chair, Dept of Ecology and Evolutionary Biology, UC Santa Cruz

## Entrainment and Impingement Losses

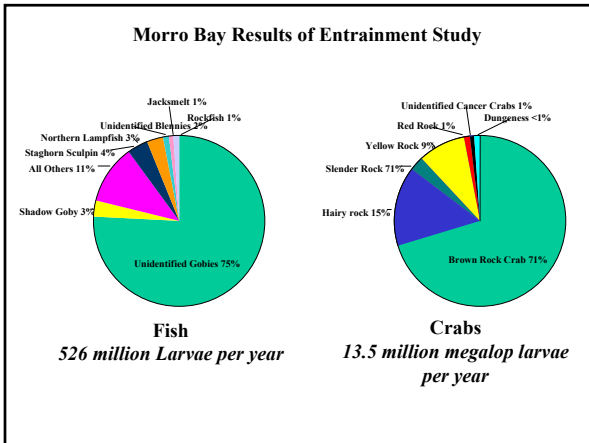
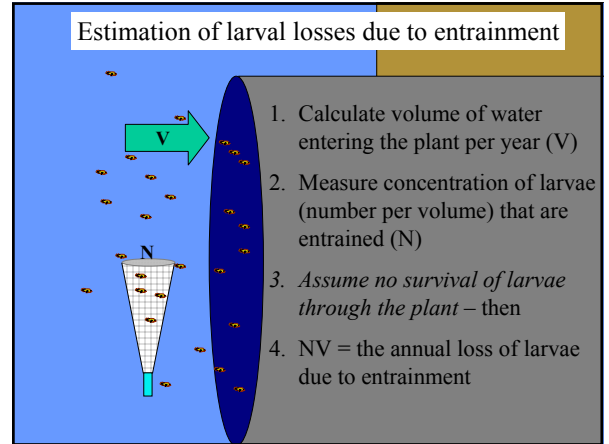
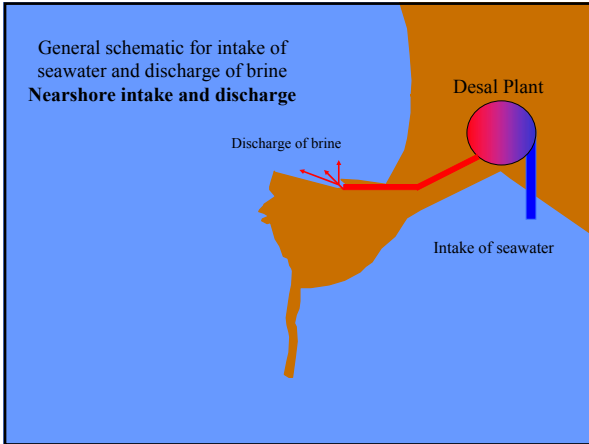
- Definitions
- Estimation of Impingement
- Estimation of Entrainment
- Estimation of Ecological Effects due to Entrainment and Impingement



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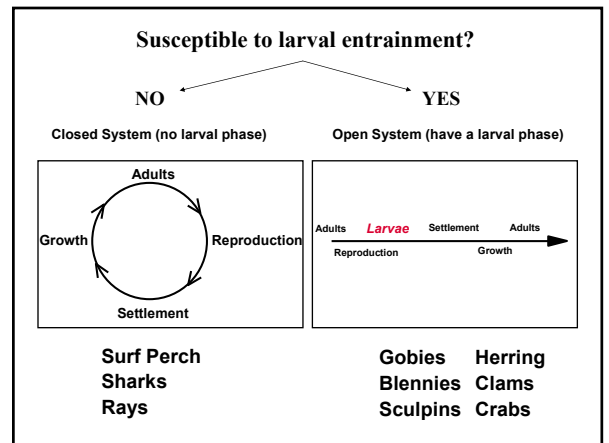


## Entrainment and Impingement Losses

- Definitions
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- Estimation of Ecological Effects due to Entrainment and Impingement

## Estimation of Ecological Effects due to Entrainment

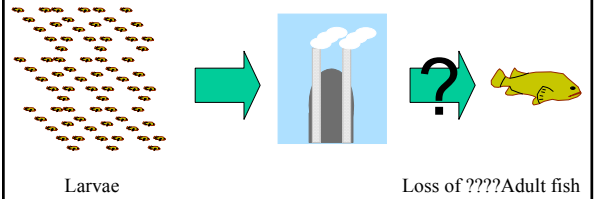
- Life history of most entrained organisms
- Methods of Estimation
  - Fecundity Hindcast (FH)
  - Adult Equivalent Loss (AEL)
  - Proportional Mortality (PM)



## Estimation of Ecological Effects due to Entrainment

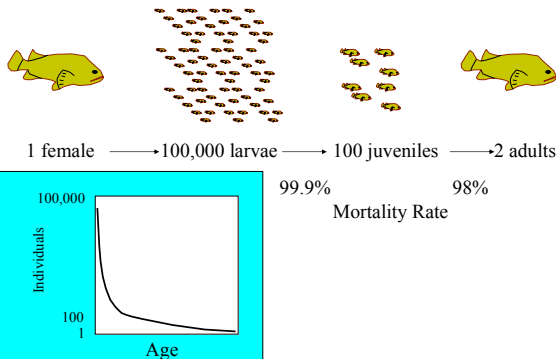
- Life history of most entrained organisms
- Methods of Estimation
  - **Fecundity Hindcast (FH)**
  - **Adult Equivalent Loss (AEL)**
  - Proportional Mortality (PM)

## Importance of larval losses due to entrainment

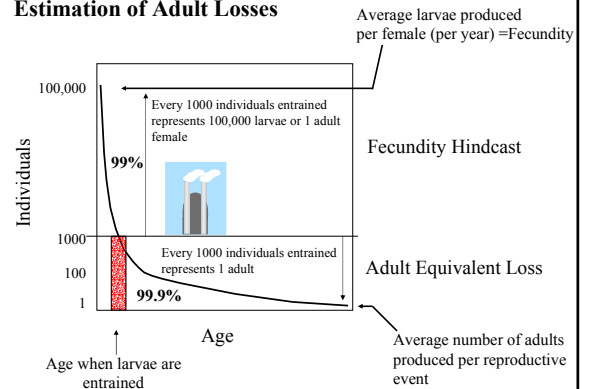


**Question: How to estimate losses to adult populations?**

## Typical reproduction and survivorship for larval producing organisms



## Estimation of Adult Losses



## Estimation of Ecological Effects due to Entrainment

- Life history of most entrained organisms
- Methods of Estimation
  - **Fecundity Hindcast (FH)**
    - Need estimate of average fecundity per female
    - Need estimate of mortality between reproduction and entrainment – **unknown for most species**
  - **Adult Equivalent Loss (AEL)**
    - Need estimate of mortality between entrainment and maturity for most species – **unknown for most species**
  - Proportional Mortality (PM)

## The Model: Calculation of Average Rate of Mortality due to entrainment

- **Determine target species**
- **Determine period when larvae are at risk**
- **Calculate rates of mortality (PM) for target species**
- **Assume that target species represent other species that were not targets**
- **Calculate average rate of mortality as the average of all PM's for targeted species**
- **This value represents the estimated rate of mortality for all species having a larval phase whose PM's were not directly determined.**

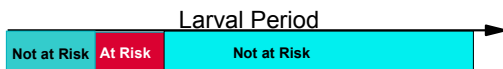
### The Model (1): Identification of Target Species

- Are commonly entrained
- Are ecologically or economically important
- Are species of special interest

### The Model: Calculation of Average Rate of Mortality due to entrainment

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### The Model (2): Determine period when larvae are at risk



d = days at risk (determined from entrainment samples)

Example	Larval Period	Days at Risk	
		Mean	Max
● Unidentified Goby	90-120 days??	4.2 days	20.7 days
● Shadow Goby	Up to 60 days	2.1 days	5.1 days
● Combtooth Blenny	90 days	4.0 days	8.1 days
● Staghorn Sculpin	56 days	15.5 days	25 days
● Jacksmelt	Unknown	9.7 days	24.8 days

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### The Model (3): calculate rates of mortality for target species

- Estimate entrainment (E)
  - Estimate number of larvae at risk (R)
- = Volume of water in area at risk x concentration of larvae
- Calculate Proportional entrainment (PE) as:
- $$- \frac{E}{R}$$

How to estimate entrainment and larvae at risk?

### Estimation of larval losses due to entrainment

- 
1. Calculate volume of water entering the plant per year (V)
  2. Measure concentration of larvae (number per volume) that are entrained (N)
  3. Assume no survival of larvae through the plant – then
  4.  $NV$  = the annual loss of larvae due to entrainment

## Estimation of larvae at risk

The map displays Morro Bay with several sampling stations marked by colored circles. A legend on the left explains the color coding:
 

- Light blue circle: Estimate for open ocean species
- Red circle: Estimate for Bay species
- Light blue and red circle: Estimate for open ocean and Bay species
- Green circle: Estimate for entrapment

 Stations are located at:
 

- Station 1 (Light blue/red): Near the Morro Bay Power Plant intake structure.
- Station 2 (Light blue/red): Further south along the coast.
- Station 3 (Red): Near the Municipal Boat Launch Ramp.
- Station 4 (Red): Near the San Luis Morro.
- Station 5 (Green): In the open ocean, south of the bay.
- Station 6 (Light blue): Further south in the open ocean.

 Other labels on the map include Morro Bay, Morro Bay Power Plant, Intake Structure, Municipal Boat Launch Ramp, San Luis Morro, Grassy Island, Sand Dunes, and Farallón Point. An inset image shows a boat with a sampling net.



- Estimate entrainment (E)
- Estimate number of larvae at risk (R)
 

$$= \text{Volume of water in area at risk} \times \text{concentration of larvae}$$
- Calculate Proportional entrainment (PE) as:

— **E/R**

Population of Larvae at risk

Daily loss due to Entrainment (PE)

Assume days at risk (d) = 3

Day 1: 1,000,000 → 30,000

Day 2: 970,000 → 29,100

Day 3: 940,900 → 28,227

Day 4: 912,673

Population of Larvae no longer at risk

Rate of Mortality (PM) =  $(87,327 / 1,000,000) = 8.73\%$

- Determine target species
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### Estimates of Mortality rate due to entrainment

<u>Species</u>	<u>Mortality Rate</u>
● Unidentified Gobies	10.7%
● Bay Goby	21.0%
● Blackeye Goby	7.5%
● Longjaw Mudsucker	8.9%
● <i>Hypsoblennius</i> spp.	18.2%
● Pacific Herring	13.4%
● White Croaker	12.9%
● Staghorn Sculpin	11.8%

## Average

**13.05%**

### Morro Bay Estimates of Mortality Rates - Fish

Species	Total Entrainment	Mortality Rate (%) (avg. period at risk)	Mortality Rate (%) (max. period at risk)
Unidentified Gobies	$3.9 \times 10^8$	11.5	42.8
Pacific Staghorn Sculpin	$1.7 \times 10^7$	5.1	
Northern Lampfish	$1.5 \times 10^7$	2.4	
Shadow Goby	$1.3 \times 10^7$	1.4	3.3
Comptooth Blennies	$1.0 \times 10^7$	49.1	72.4
KGB Rockfishes	$6.4 \times 10^6$	2.4	
Jacksmelt	$6.3 \times 10^6$	21.9	44.2
White Croaker	$3.0 \times 10^6$	2.1	
Pacific Herring	$3.0 \times 10^6$	1.2	1.7
Cabezon	$2.9 \times 10^6$	3.7	
Average Mortality Rates			
	All species	10.1%	32.8%
	Bay Species	17.2%	32.8%
	Crabs	2.0%	

### Diablo Canyon

#### Estimates of Mortality rate due to entrainment

Species	Mortality Rate
● Smoothhead Sculpin	17%
● Monkeyface Prickleback	17%
● Kelpfishes	41%
● Snubnose Sculpin	2%
● Blackeyed Goby	13%
● White Croaker	1%
● Blue Rockfish	1%
● KGB Rockfish	2%

### SONGS

#### Estimates of Mortality rate due to entrainment

Species	Mortality Rate
● Queenfish	13%
● Giant Kelpfish	7%
● White Croaker	6%
● California Grunion	5%
● Black Croaker	4%
● Corbina	4%
● Jacksmelt	3%
● Cheekspot Goby	3%

### Interpretation of estimate of LOSS (FH, AEL and PM)

- With FH and AEL we can estimate adult loss
- With PM we can estimate proportional larval loss

– **Question: what level of loss is environmentally important?**

- What counts as important?

- Local
- Regional
- National

### Habitat Equivalency – a way to interpret loss

- Method allows for conversion of organismal loss to habitat
- Can work for any source of loss
  - Impingement or entrainment
- Can work for any estimate of loss (e.g.)
  - Fecundity Hindcast
  - Adult Equivalent Loss
  - Proportional Mortality

### Morro Bay Example: Proportional mortality of a Bay Species = 17%

1. Calculate area of Bay (B)
2. Then the habitat required to compensate for larval losses =  $B \times 0.17$

Example: area of Bay = 2000 acres

Then  $(2000 \times 0.17)$  **340 acres of new bay habitat would be needed to produce larvae equivalent to losses =**

**Area of Production Foregone**



### Comparison of estimated entrainment impacts at four coastal powerplants

Site	Gallons per minute	Intake	Estimated larval loss	Population at risk	Area of production forgone
Moss Landing	250,000	In harbor	13-28%	Elkhorn Slough (3000 acres)	390-840 acres
Morro Bay	258,000	In Morro Bay	17-32%	Morro Bay (2000 acres)	340-640 acres
Diablo Canyon	1,200,000	In Diablo Cove	4-24%	Coast of California	5-50 km of coastline
SONGS	1,660,000	6000-8000 ft offshore	3-13%	Southern CA Bight	3-13% of S. Cal Bight

### Impingement considerations (adults and juveniles)

- Length of intake is critical to impingement rate
- Intake velocity is also important (<1 ft per second is best)
- Impingement can be mitigated by diversion systems
- Location of intake will greatly affect species composition that is impinged
- Estimation of loss is generally fairly easy
- Estimation of impact is difficult

### Entrainment considerations (generally larvae and other plankton)

- Intake velocity is critical
- Intake location is important in determining species composition entrained
- Most regulators assume 100 percent mortality
- There are currently no obvious diversion or filtration systems for coastal systems
- Estimation of loss is relatively easy
- Estimation of impact is difficult
- Estimation of compensation or mitigation is difficult and almost always contentious

### Cumulative Impacts The new frontier

